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Abstract of Thesis Presented to the Graduate School
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PREDISPOSING FACTORS FOR KNEE INJURY IN
AIRFORCE ACADEMY CADETS

By

Laura C. Fields

May 2001

Chairman: Dr. Denis Brunt
Major Department: Department of Physical Therapy

Both men and women are at high risk for sustaining knee injuries during their Air Force career. A significant amount of lost duty time and resources are spent each year on the treatment of knee injuries sustained by active duty military personnel. Information regarding lower extremity injury to military members is noted in the scientific literature for the Army, Navy and Marine Corps. The Air Force is the only military branch that is lacking in this area of study. The purpose of this study was to establish predisposing factors that put Air Force Academy Cadets at risk for knee injury. Six variables: single-leg hop test for distance, hamstring length, quadriceps strength, hamstring strength, ACL laxity and navicular drop were measured for each limb on 204 Cadets. A Chi Square analysis was conducted to determine if any of the above measurements were significantly different in the injured group as compared to the noninjured group. For 6 months after testing the cadets were tracked for injury occurrence.

Results: Stepwise mechanical binomial logistic regression was performed (inclusion criteria of 0.05, exclusion criteria of 0.1) to relate to injury status of the subject to anthropometric measures and gender. From the logistic regression, the variables that were significant contributors to determining injury were identified. Level of significance was set a priori at $P < 0.05$. Left navicular drop (0.005) appeared to be significantly different between injured and noninjured groups. The highest R squared value (0.13) indicates a low predictive value for this model. Males and females appeared to have the same rate of injury (30.8% males, 33.3% females). Of the injured cadets, 65.6% failed to report their injury to medical providers with males responsible for 70.8% of the reporting failure.

Conclusion: The results of our study indicate that static measurements may not be the best predictors for dynamic injuries. This agrees with other prospective studies. The previous studies that noted significant findings were retrospective or theoretical in design. The power of our study was low due to the variety of knee injury types that then led to low numbers per injury. It is possible that a Type II error occurred because of this fact. Demographic and epidemiological data for the Air Force was noted to be similar to other military service studies in respect to rate of injury, perceived level of fitness, weekly exercise rate and ethnic background distribution. The high percentage of failure to report injury was noted in our study and was consistent with previous military studies. This alarming trend needs to be addressed for all military services. Continued research on knee injury and prevention of injury needs to be conducted for the future safety of Air Force military members.

PREDISPOSING FACTORS FOR KNEE INJURY IN AIR FORCE ACADEMY CADETS

By

LAURA C. FIELDS

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF HEALTH SCIENCE

UNIVERSITY OF FLORIDA

2001

Dedicated to the United States Air Force
and to my son, David

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CHAPTER 1
INTRODUCTION

Statement of Problem

In the past decade, the military was asked to create operational efficiencies, yet remain prepared to defend America and to protect her interests. All members of the Armed Forces undergo rigorous training programs for the purpose of ensuring a fit and ready force to accomplish this mission. This is especially critical in the current milieu of increasing deployments. Many military deployments are "military operations other than war," a spectrum of assignments that involve less than serious combat.[7] The military is asked to support a variety of deployments (e.g., Southwest Asia, Somalia, Rwanda, Haiti, and the former Republics of Yugoslavia), campaigns (e.g., Operation Desert Shield and Operation Desert Storm during the Gulf war in Iraq), as well as to maintain strategies (e.g., Operation Joint Endeavor in Croatia and United Nations' peacekeeping forces in Yugoslavia). At the same time, areas of unrest such as Bosnia, North Korea and Yugoslavia continue to demand military intervention and tap its already strained resources.[26,27] These operations are ongoing despite the continuous downsizing of the military. Intense training is required of the men and women of the Air Force to carry out such missions. As a result, both men and women are at high risk for sustaining knee injuries during their service carreer.[13,16,19,24,28]

According to the latest demographics for the Air Force,[27] 348,818 individuals are on active duty of which approximately 68,000 are officers. The average age for an officer

is 35 years old. Women make up 18.9% of the Air Force and the percentage is rising. Women first began entering pilot training in 1976, navigator training in 1977 and fighter pilot training in 1993. Racial minority representation has risen from 14% in 1975 to 25.9% in 2001. Whites make up 74.1%, 16.2% are black, 4.9% are Hispanic, and 4.9% other ethnic backgrounds complete the diverse cultural picture of the Air Force.[27]

Mobility teams or teams that are deployable come from this pool of personnel and are required to be physically fit and ready for deployment at a moment's notice. Factors that predispose this pool for injury need to be recognized and targeted for prevention so that the Air Force is strong and prepared for any contingency.

The cost of one routine anterior cruciate ligament repair, with no other complications, ranges from approximately $8,000 to $12,000 per patient. This cost only encompasses the cost of the surgeon, anesthesia and hospital (operating room and recovery). This does not include the cost of rehabilitation which runs anywhere from 16 weeks to 24 weeks. This monetary approximation also fails to consider the invaluable cost of the lost duty time that occurs. In a deployment setting it is often not logistically possible to replace a team member quickly if at all. If a key person cannot do his or her job in a timely manner, other members who depend on that person may not be able to do *their* job and, therefore, the success of the mission may be a stake. Information regarding preventing lower extremity injury to military members is noted in the scientific literature for all services except the Air Force.[10,11,13,16,21]

The purpose of this study was to establish risk factors associated with knee injuries in Air Force Academy Cadets.

Significance

The data obtained from this investigation may be able to provide Air Force personnel the ability to identify predisposing variables associated with knee injuries. This would allow the military to develop efficient knee injury screening batteries and training protocols to decrease knee injury and severity. The implementation of these tools may result in improving the military's ability to have a fit and ready force able to meet its burgeoning and diverse mission.

CHAPTER 2
LITERATURE REVIEW

Deployment Injuries

In a review of the documented literature citing injuries during deployments and military training, orthopedic injuries are consistently one of the leading reasons for military members to be nondeployable.[2,10,13,19,28] In a survey of the British army's orthopedic casualties evacuated from deployment sites, 55% of all evacuations were related to bone and soft tissue injuries, with sporting activities the most common cause of injury. Orthopedic conditions were by far the greatest single cause of repatriation, with 29% of those injuries caused by sport activities.[11]

Krentz et al.[31] reported during a 6-month deployment on board a US Navy aircraft carrier, 36% of reported injuries resulted in lost duty time. Recreational injuries represented 19% of all injuries, and 25% of all lost duty injuries. The sports of volleyball, basketball and football were the most likely activities to cause injuries resulting in lost duty time. Injuries involving the lower extremity were highly associated with increased risk of lost duty time.[31,33] Injury prevention in similar environments should be addressed for both recreational and work-related activities.

While deployed to the Persian Gulf for Operation Desert Shield, 73 patients underwent elective arthroscopy while on-board the USNS Mercy. Of the 71 men and 2 women (with a mean age of 27 years), 47% presented with meniscus tears, 23% with torn anterior cruciate ligaments (ACL), and 7% with chondromalacia. Of the patients

requiring surgery, 66% were returned to duty at an average of 6 days postoperatively.[11] Combat injuries, which include injuries sustained from parachuting landings and penetrating shell fragments, affected the lower extremity at a higher percentage than other areas of the body.[10,20,31]

Epidemiological Studies

Jones[28] conducted a study to assess the incidence, types, and risk factors for training-related injuries among young men undergoing Army infantry basic training. Before training, physical fitness was measured and questionnaires were compiled. Eighty percent of all training-related injuries involved the lower extremity.

Almeida[2] conducted a study for the Marine Corps that investigated the lower extremity injury rates of both men and women completing 11-12 weeks of boot camp. Questionnaires and medical record reviews were completed. Female recruits were more likely than their male counterparts to report an injury and less likely to have an unreported injury. The conclusion was that both males and females sustained relatively equal lower-extremity injury, with patello-femoral and ilio-tibial band (ITB) syndromes representing the highest rates of injury.

A controlled trial study conducted by Gardner et al.[20] for the Army examined the effect of a viscoelastic polymer insole for the prevention of lower-extremity stress fractures. Unfortunately, the elastic polymer did not prevent stress reactions of bone during a 12-week training session. However, the investigators observed a strong trend that if an individual had a history of increased physical activity then the rate of stress injury decreased. Interestingly, the authors also noted a higher stress injury rate in white recruits compared to black recruits.[20]

Schneider and colleages[40]conducted a study evaluating the risk of re-injury among Army Airborne soldiers. Lower extremity and low-back musculoskeletal injuries were identified from outpatient medical records. Two models were used to identify risk factors for initial and recurrent injuries and noted that previously injured personnel were seven-times more likely to become injured again. Traumatic injury versus overuse injury was noted to be a significant precursor for reinjury. Additionally, the authors noted that other variables such as ethnic background, medical provider training, previous physical fitness, and even alcohol consumption and marital status were significantly associated with reinjury.[40] Air Force personnel match many of the demographics of the previously mentioned studies[2,20,28,31,40] and are as much at risk for lower extremity injury as the Army, Navy and Marines. The risk may be in a different venue but the risks are still present and need to be addressed for prevention, whether it is in a Deployment Aircraft hanger or an Air Force training base.

Predisposing Factors for Knee Injury

It's been established that both men and women of the Armed Forces are at high risk for sustaining knee injuries during their service career.[13,16,19,24,28] Several researchers conducted a number of studies aimed at finding a definitive cause of knee injury.[3,4,6,8,15,18,23,49] Common upper-leg injuries include knee sprains, hip and knee muscular strains, iliotibial band syndrome, patellofemoral knee pain, meniscus and anterior cruciate ligament (ACL) injury. Meniscus and ACL injury often require surgery with a relatively long rehabilitation period. In addition to the exorbitant monetary cost, these injuries are two of the most costly lower-extremity injuries for the military in respect to mission readiness and resource utilization.[26] With the increasing numbers of women

entering the Armed Forces and taking on combat roles, it should be noted that there is documented evidence of increased ACL injury to women when compared to males doing the same task.[3,4,6,8,18]

The kinematics of the knee involve passive ligament stability and dynamic muscle efficiency.[17,36,48] The curvature of the femoral and tibial articulation surfaces and the major four ligaments of the knee determine its predominant kinematic characteristic. The distal portion of the lateral femoral condyle has a larger radius of curvature than does the distal portion of the medial femoral condyle.[17] During the first 10-15 degrees of flexion, the femur rolls posteriorly a greater distance on the lateral tibial plateau than on the medial tibial plateau.[48]

This difference in posterior movement is associated with a coupled passive internal axial rotation of the tibia with respect to the femur.[36] The reverse movement to full extension produces a coupled external rotation of the tibia, also known as the screw-home mechanism.[17,48] With flexion, posterior movement of the tibio-femoral contact also changes lever arms of the muscles crossing the knee joint and can have a substantial influence on function.[17,36,48]

The cruciate ligaments significantly influence knee kinematics.[36,48] The length and degree of tension developed in the cruciates changes during flexion and extension. The passive action of the cruciate ligaments is responsible for the sliding movement that occurs when the knee is flexed greater than 20 degrees.[17] As the knee continues to flex, the anteromedial portion of the ACL becomes taut, preventing pure rolling of the femur, thus initiating sliding between the femur and the tibia at 20 degrees. At the same time during this flexion moment, the posterolateral portion becomes lax.[17] The reverse is true

for extension of the knee. With extension, the posterolateral fibers become taut and the anteromedial fibers become lax.[48] With loading of the knee, the ACL is needed for equilibrium near full extension, whereas the posterior cruciate ligament (PCL) is required for high angles of flexion.[36] The critical angle at which no ligamentous action occurs lies near mid-range for the quadriceps, at near-extension for the hamstrings, and at near high-flexion for the gastroc-soleus complex.[17,36,48] This is the point where muscles of the hip and knee are at risk for injury.

Knee Sprains and Muscular Strains

Wojtys et al.[47] have documented the role of muscle activity in knee joint protection by two pathways: 1) relief of ligamentous strain; and 2) impact absorption of loads transmitted through the lower extremity. These functions are achieved by generating resistance to knee motion, also known as joint stiffness,[47] through quadriceps, hamstring, and gastrocnemius muscle contractions about the knee, thus protecting the passive restraints of the knee. Muscle injury, apart from contusions, occur from excessive stresses acting on the musculature, either eccentrically or concentrically.[48] These muscular injuries are also known as strains, tears, pulls, etc.,[17,36] and most often occur at or around the musculotendinous region.[48]

Previous researchers[1,9,24] investigated the relationship between the flexor/extensor strength ratios about the knee and the incidence of knee injury. The study conducted by Aagaard and colleagues[1] attempted to quantify antagonist coactivation and the resultant moment of force generated by the hamstring muscles during maximal quadriceps contraction in slow isokinetic knee extension. Maximal concentric quadriceps contractions and maximal eccentric hamstring contractions were recorded.[1] Substantial

hamstring coactivation was observed during quadriceps agonist contraction. The results showed that substantial antagonist flexor moments are generated. The antagonist hamstring moments potentially counteract the anterior tibial shear and excessive internal tibial rotation induced by the contractile forces of the quadriceps near full knee extension.[1,9,25] During this movement, the authors suggested that hamstring coactivation assists the mechanical and neurosensory functions of the ACL. A number of researchers[1,23,46,48] noted that hamstring musculature is a major contributor to the dynamic stabilization of the knee and an agonist for the ACL.

The percentage of women in the Air Force is increasing significantly. Now that women are eligible to participate in combat roles, their next hurdle is to pass the physical fitness requirements that come with the job. Are Air Force women physically prepared for this new challenge? In a study conducted by Wojtys et al.,[47] female athletes took significantly longer than male athletes to generate maximum hamstring muscle torque during isokinetic testing. They also found that the muscle recruitment order in some female athletes was markedly different. The female athletes appeared to rely more on their quadriceps muscles in response to anterior tibial translation, creating increased stress to the ACL.[47]

Noyes et al.[38] reported that 78% of all ACL injuries were noncontact in nature. Three major mechanisms for injury were identified: straight knee landing from a jump, cutting and turning, or sudden deceleration. Another mechanism for knee injury involves running, a standard training requirement for the military especially in the field on a variety of terrains.

Patello-Femor`al Pain Syndrome

Another common knee syndrome that afflicts the military is Patello-Femoral Pain Syndrome. Several studies have shown that intrinsic factors relative to this syndrome include excessive navicular drop or over-pronation at the subtalar joint (STJ), which creates excessive internal rotation of the tibia. Biomechanically, this action places increased stress on the ACL and at the patello-femoral joint thus putting the soft tissues at risk for injury.[5,42,15,8,48]

The structural make-up of the subtalar joint[36,17] includes a snug congruency of the tibia to the talus. As the STJ pronates, the talus plantar flexes and medially rotates, bringing the tibia into internal rotation. If there is excessive pronation of the STJ, the tibia excessively internally rotates as well, increasing stress on the cruciate ligaments.

During gait, as the body passes over the foot, the knee must go into extension. Normally, this happens as the STJ starts to supinate, the tibia externally rotates until it is aligned under the femur and the knee can fully extend. If the STJ is abnormally pronated and the tibia is excessively internally rotated; however, the tibia cannot externally rotate in time to meet the femur.

Tiberio[42] proposed a theory that the femur compensates for this lack of timely external rotation by internally rotating itself to meet the tibia. As a result, the patella is displaced medially and the Q angle is increased. This increases the lateral compression forces on the patella, leading to dysfunction and pain. Powers et al.[39] supported this hypothesis by demonstrating that rearfoot varus is greater in subjects with Patello-Femoral Pain Syndrome.

These abnormal biomechanical stresses may be corrected with the proper orthotics, therefore, preventing stress and injury at the knee. From the standpoint of a

clinical evaluation, identifying one of these factors may alert the examiner to inspect other anatomical factors that may cause an increase in stress on the knee joint and thus increase incidence of knee injury.

Trimble et al.[39] conducted a pilot study that measured forty-three active, healthy college-aged subjects without prior lower extremity pathology. Postural measures were taken of the right leg. The investigators noted that there was a significant correlation using a final regression model in comparing navicular drop to knee laxity. It appeared that gender, knee recurvatum, and thigh/foot angle were not significant predictors of ACL laxity but that navicular drop was a strong predictor of knee laxity. The investigators concluded that foot posture may have greater impact on knee laxity than other lower extremity postures.

Prevention of Injury Studies

Previous studies[10,11,16,20,23] have analyzed training regimes for the Army, Navy and Marines in an effort to identify preventable injuries of the lower extremity. Investigators for the Army[34] illustrated the effect of Wolff's law;[16] that bone adapts to mechanical stresses placed on it. The authors performed three prospective epidemiological studies that focused on the effect of pre-military-induction sport activities on the incidence of lower-extremity stress fractures during infantry basic training. Their study noted that recruits, who had participated in at least two years of basketball, had increased their bone stiffness in the lower extremity which decreased the incidence of stress fractures during basic training.[34] Hartig et al.[23] conducted an intervention study for the Marines to investigate if increasing flexibility of the musculotendinous unit of the hamstrings decreases the number of extremity overuse

injuries that occur in military basic trainees. A sample of trainees underwent three hamstring-stretching sessions in addition to their scheduled fitness program. At the end of the 12-week basic training, the experimental group had significantly lower incidences of overuse injuries to their lower extremity.[23]

Prevention studies such as these need to be implemented for the Air Force. The majority of the Air Force is made up of land-based crews that support flight operations. This support crew is made up of mechanical, logistic, operational, and medical specialties, just to name a few, all of which are critical before a pilot can even leave the ground. More studies need to be conducted for the Air Force in this area so that these critical, land-based, personnel are protected so that they can effectively and efficiently accomplish the Air Force mission.

Specific Aims

The specific aim of this study was to identify the relationship between static anthropometric and strength measurements of the knee and to track the injury history in US Air Force Academy Cadets.

Hypothesis

For the investigation purposes of this study, several hypotheses were explored.

1. The null hypothesis stated that knee injury cannot be predicted by the measures tested.
2. Cadets displaying a low hamstring-to-quadriceps ratio of strength would have a significant predisposition to knee injury.
3. Cadets with extreme measures for hamstring extensibility or tightness would have a significant predisposition to knee injury.
4. Cadets with excessive ACL ligamentous laxity would have a significant predisposition to knee injury.
5. Cadets with excessive navicular drop would have a significant predisposition to knee injury.

CHAPTER 3
METHODOLOGY

Subjects

Two hundred four Air Force Academy Cadets volunteered to participate in this study. Each cadet provided written, witnessed, informed consent for participation. This study was reviewed and approved by the Institutional Review Board of the University of Florida in Gainesville as well as from the United States Air Force Academy in Colorado Springs, Colorado. Demographic information was obtained including age, height, weight, race, gender, history of injury, fitness level and athletic history. The subjects' mean age was 20 years old with a range of 17 to 25 years of age.

Definition of Injury/Inclusionary Criteria

The cadets' injury would be entered if it was training/sports related and: 1) kept the cadet out of training or competition on the day following the injury or, 2) required medical attention of any kind beyond the use of ice or wrapping. Exclusion criteria consisted of inconsequential injuries such as minor muscle strains with no visible swelling, ecchymosis or weakness, skin lacerations and abrasions.[37]

For the 6 months after the initial assessment, incidence of injury was documented and tracked by the investigators for this study via electronic mail on a monthly basis.

Instrumentation

A universal goniometer, a knee arthrometer using a KT-1000 (MED-metric Corp., San Diego, Calif.) and a hand-held dynamometer (Nicholas Manual Muscle Tester,

Lafayette Instrument Co., Lafayette, IN) were used for the measurements taken in this investigation.

Measurements

Hamstring Flexibility Assessment

With subjects in the supine position, the hip and knee of the tested extremity were positioned at 90 degrees of flexion with the use of a goniometer. Subjects stabilized the hip by placing both hands around the distal thigh just proximal to the knee. Subjects were then asked to maximally extend their knee while maintaining the hip at 90 degrees of flexion. Measurement of the hamstring flexibility was documented as the number of degrees from complete knee extension. Two practice measurements were taken followed by one test measurement.

Hamstring Strength Assessment

Hamstring strength was assessed isometrically with the Nicholas Manual Muscle Tester. Subjects were prone and the knee to be tested was positioned at 30 degrees of flexion with the use of a goniometer. This angle was chosen because it represents the angle of maximal isometric force generation for the hamstrings.[44] The force pad of the tester was placed 5 cm proximal to the later malleolus on the posterior aspect of the lower leg. Four warm-ups were allowed; one each at 25,50, 75 and 100% of perceived maximal effort. Subjects were instructed to gradually build up to a maximal effort over 1 to 2 seconds. The tester performed two final tests with the subject exerting 100% effort for 3 seconds. The numeric reading on the dynamometer was annotated. The numeric readings were in foot-pounds of pressure (1 ft lb=2 lb).

Quadriceps Strength Assessment

The Quadriceps strength was assessed isometrically with the Nicholas Manual Muscle Tester. All subjects were seated in a chair with stability brakes on the legs to avoid movement during testing. The tester was braced against the wall to avoid any movement thus insuring accuracy of testing. The testing procedure was conducted with the knee at 60 degrees of knee flexion, as measured by the tester using a full circle universal goniometer. This angle was chosen because it represents the average angle of maximal peak force of the quadriceps muscle group as determined by isokinetic dynamometry.[44]

The hand-held dynamometer was positioned two finger widths above the lateral malleolus on the anterior aspect of the tibia. The subjects were asked to hold the sides of the chair while performing isometric knee extension contractions.

Four warm-ups were allowed; one each at 24, 50, 75 and 100% of perceived maximal effort. Subjects were instructed to gradually build up to a maximal effort over 1-2 seconds. The tester performed two more tests with the subject exerting 100% effort for 3 seconds. The numeric reading on the dynamometer was annotated. The numeric readings were in foot-pounds of pressure (1 ft lb=2 lb). The maximum peak force for the three trials of 100% was used to determine quadriceps muscle performance.

Single-Leg Hop For Distance Test

Three single-leg hop tests were used to assess lower extremity performance of functional strength and balance. All tests required one practice trial followed by two test trials for both legs. All tests were randomly performed. The single-leg hop tests were used following procedures as described by Worrell et al.[50] A 3-m strip of tape was

marked in centimeters and placed on the floor. A video camera was placed at floor level to document on film the landing for each jump. A practice trial was performed in which subjects were instructed to stand on one leg in a crouched position with arms by their sides. Subjects were positioned with their toes touching the zero mark and instructed to hop forward as far as possible and land on the tape with both feet for safety. The horizontal distance to their heels was then measured for each trial. The videotape was used as back up for accuracy of measurement.

Ligament Laxity Testing

Anterior cruciate ligament laxity was measured with a knee arthrometer using a KT-1000 (MED-metric Corp., San Diego, Calif.). Both legs of the subject were positioned over a bolster with the knee angle approximately at 30 degrees of flexion and thighs stabilized with a belt to maintain hip rotation to neutral. The arthrometer was strapped to the subject's tibia. The following pounds of pressure; 15lb, 20lb and 30lb, as well as a manual maximal pressure, was exerted in a posterior to anterior translation, while the subject's patella and thigh are stabilized by the tester. The number of millimeters of anterior tibial translation was measured and recorded.

Navicular Drop Test

The navicular drop test was used as a clinical measure of pronation. The tests were performed following procedures as described by Louden et al.[32] The most distal point of the navicular tuberosity was marked on the medial side of the foot. The subjects were asked to begin this test seated. The investigator palpated the subtalar joint in the neutral position, marked and measured the position. The subtalar joint neutral position is defined as the position of maximum congruency between the talus and the calcaneus.

Palpation of subtalar neutral was performed by palpation of the talar head on both the medial and lateral side of the joint. The height of the navicular was measured from the floor to the most distal point on the navicular bone. Subjects then stood with the foot in a relaxed position. The navicular distance was measured again. The difference between the two navicular distances was calculated. A difference value of 6 mm was considered normal, greater or equal to 9 mm was considered high, and values less than 6 mm was considered low which may be considered as predisposing factors for injury.[32]

Instrumentation Reliability/Validity

Measurements from two hand-held dynamometers (HHD) were compared with measurements obtained from a Kin-Com isokinetic dynamometer. The Kin-Com measurements were used as criteria to determine validity of the HHD. Analysis of variance showed no significant difference between the Kin-Com and the HHD measurements.[44] A study of reliability and validity of the hand-held dynamometer as applied to adults was conducted to evaluate the component-isometric strength of the knee and the elbow. Pearson product-moment correlation coefficients were calculated between the Kin-Com and Nicholas HHD and found to be relatively high (0.85). Using stabilization techniques, isometric torque values were taken of knee extension and elbow flexion on separate days with the Nicholas MMT and a Cybex II dynamometer. Pearson product-moment correlations of these two instruments ranged from 0.64 to 0.76 ($P < 0.05$). Based on 1 day of testing intrarater correlation coefficients for the Nicholas (MMT) ranged from 0.97 to 0.99 ($P < 0.05$). In like fashion interrater generalizability coefficients were quite high ($G = 0.97 – 0.98$).[41]

Multiple reliability studies have been performed using the KT-1000 knee arthrometer.[22,35,] High reliability coefficients were found in the measurements of anterior tibial translation.[21] Reliability of test measures is critical in any research project. Intrarater reliability was assessed for each independent variable using a test retest method on 6 subjects. Postural measurements were repeated on the same subject on the same day approximately 30 minutes apart. Intraclass Correlation Coefficients were found for each variable using Alpha scale (Appendix C).

Procedures

Two hundred and four Air Force Academy Cadets volunteered to participate in this study. Each cadet provided written, witnessed, informed consent for participation. Each cadet filled out a questionnaire describing demographic data and personal history of sports, exercise and injury history. Each cadet performed the single-leg hop for distance test followed by quadriceps strength assessment, hamstring strength assessment, hamstring length measurement, ACL laxity measurement and navicular drop measurement. Each cadet was emailed once a month by the investigators for six months to track injury occurrence.

Design And Analysis

This study is a prospective design. Analyses included descriptive, chi-square and logistic regression analysis. One independent variable, injury, was monitored during the course of this study: knee injury. The 6 dependent variables were assessed individually first. The investigated variables for this study included: single-leg hop test for distance, hamstring length, quadriceps strength, hamstring strength, hamstring/quadriceps strength ratio and navicular drop. Means and standard deviations of continuous variables, such as

body height, body weight, and joint ranges of motion, were calculated. The injury rate was calculated by dividing the total number of injuries by the total number of subjects studied. The injury incidence (percentage of enrollees injured) was calculated by dividing the number of subjects with one or more injuries by the total number of subjects studied. A Chi Square analysis was used to assess the differences of the dependent variable between the two groups. Stepwise mechanical binomial logistic regression was performed (inclusion criteria of 0.05, exclusion criteria of 0.1) to relate the postural variables to injury status of the subject (yes=1, no=0). From the logistic regression, the variables that were significant contributors to determining injury were identified. Level of significance was set a priori at $P < 0.05$.

CHAPTER 4
RESULTS

Descriptive Analysis

Two hundred and four Air Force Academy Cadets volunteered to participate in this study. The groups of subjects were made up of 76% (n=156) males and 24% (n=48) females. The subject group was comprised of freshmen through senior college students, ages 17 to 25. The average age was 20 years old with 19.6% freshmen, 30.4% sophomore, 27.5% junior and 22.5% senior. The ethnic background of the cadets that participated in the study was 84.8% whites. The rest of the cadet's ethnic background included 7.8% Hispanic, 2.9% African-Americans, 2.0 Asian and 2.5% of other ethnic origins. The mean weight for males was 169.8 ± 17.8lbs (77.2 ± 8.1 kilograms) and a mean height of 71 ± 3 inches (180.3 ± 6.9 centimeters). The mean weight of females was 138.4 ± 17.1 lbs (62.9 ± 7.8 kilograms) and a mean height of 66 inches (167.6 ± 8 centimeters). For the question of current level of physical fitness, 96% (n=196) of the 204 Cadets rated themselves in "good" to "excellent" physical fitness (Table 4.1). For the question of exercise frequency during the past year, about 85% (n=172) of the cadets reported that they exercised 3 times to 6 times per week (Table 4.2). Following injury, 65.2% (n=133) of the cadets reported they were able to return to 100% of prior physical level. At the time of testing, 60.8% (n=124) of the cadets reported their lower extremity function was at 100% with 95% (n=26) and 90% (n=22) being the second and third most frequent response, respectively.

Table 4.1 Cadet's perceived rating of current physical fitness.

Perceived Physical Fitness	Frequency	Percent
Fair	8	3.9
Good	62	30.4
Very Good	98	48.0
Excellent	36	17.6

Table 4.2 Cadet's reported frequency of exercise in past year.

Exercise Frequency during past year	Number of cadets	Percent
3/week	35	17.2
4/week	41	20.1
5/week	48	23.5
6/week	48	23.5

Comparing the means between males and females of hamstring lengths, males exhibit 30%-40% tighter hamstrings than women (12.6 degrees knee flexion versus 5.06 degrees knee flexion) for both legs. Analysis of quadriceps and hamstring strength and the ratio between men and women revealed that males had 62%-63% the strength of hamstrings to quadriceps. For females, the average strength of the hamstrings was 54%-56% as strong as their quadriceps.

For the female cadets, 39.6% (n=19) were using birth control. Responding to the question of menstrual cycle regularity, 83.3% (n=40) reported no irregularities in their cycle and 18.8% (n=9) reported irregular menstrual cycles.

Injury Incidence and Distribution

After the questionnaire and the testing procedures involving the hip and knee, the investigators tracked the cadets for the next 6 months for injuries (Table 4.3). A variety of injuries were reported, fitting the inclusion criteria as noted in the methods section.[37] A variety of injuries involving the hip and knee were reported.

Table 4.3 List of knee injuries tracked for six months

INJURY TYPE	FREQUENCY
Knee Sprain	8
Groin Strain	4
Quadriceps Strain	4
Iliotibial Band Syndrome	3
Hamstring Strain	2
Medial Meniscus Tear	2
ACL Tear	1
Patellar Tendonitis	1
Patella-Femoral PS	1

Of the 204 cadets, 31.4% (n=64) of the cadets experienced injuries during the 6-month tracking time frame. Of the male cadets tested, 30.8% (n=48) were injured and of the female cadets, 33.3% (n=16) were injured during the 6 months of injury tracking.

For the first series of injuries, 60.9% (n=39) of the injuries involved the right leg. The left leg made up 39.1% (n=25) of the injuries. For cadets that were injured twice, 89.5% (n=17) of the injuries involved the left leg. Of the injured cadets, 65.6% (n=42) did not report their injury to medical providers. A repeat of this occurred when 63.2% (n=12) of the cadets that experienced their second injury failed to report it to medical providers. The same was true for cadets sustaining three injuries (n=3).

Table 4.4 Mean values of injured versus uninjured males and females for the six tested variables

INDEPENDENT VARIABLES	MALES UNINJURED (n=107)	MALES INJURED (n=18)	FEMALES UNINJURED (n=32)	FEMALE INJURED (n=9)
	Mean	Mean	Mean	Mean
Right Single-leg hop for distance (cm)	76.24	76.57	62.17	64.87
Left Single-leg hop for distance (cm)	77.12	77.10	62.82	65.78
Right Hamstring Length (% knee angle)	12.20	9.50	4.75	6.22
Left Hamstring Length (% knee angle)	10.99	9.17	3.81	4.78
Right H/Q Strength Ratio (% hamstring to quadriceps strength)	0.6361	0.6024	0.5582	0.5332
Left H/Q Strength Ratio (% hamstring to quadriceps strength)	0.6514	0.6215	0.5726	0.5451
Right ACL Laxity (KT-1000 in mm)	7.28	8.89	8.39	8.06
Left ACL Laxity (KT-1000 in mm)	7.51	8.64	8.39	7.06
Right Navicular Drop (mm)	1.04	0.92	0.87	1.00
Left Navicular Drop (mm)	0.94	0.95	62.17	1.00

Of all the lower extremity injuries, 42.2% (n=27) involved the knee and the musculature above knee up to the hip. Of the second injuries documented, 31.6% (n=6) involved the knee and above and 20.0% (n=1) of the third injury involved the knee and above as well. Of the injuries incurred, one ACL rupture, 2 meniscus injuries and a variety of muscular strains (quadriceps, hamstrings, hip flexor, groin) were documented. General knee sprain was the most frequent complaint of the knee injuries (n=8). Table 4.4 illustrates the mean measurements of the independent variables comparing male cadets injured versus non-injured and female cadets injured versus non-injured (Table 4.4).

Chi Square Analysis

Six dependent variables, single-leg hop test for distance, hamstring length, quadriceps strength, hamstring strength, ACL laxity and navicular drop were measured for each limb on 204 cadets. A Chi Square analyses was conducted to determine if any of the above measurements were significantly different in the injured group as compared to the non-injured group. Level of significance was set a priori at $P < 0.05$. No significant differences were noted for any of the measurements (Appendix D).

Logistic Regression Analysis

Stepwise mechanical binomial logistic regression was performed (inclusion criteria of 0.05, exclusion criteria of 0.1) to relate to injury status of the subject (yes=1, no=0). From the logistic regression, the variables that were significant contributors to determining injury were identified through Forward and Backward Stepwise Analyses. Level of significance was set a priori at $P < 0.05$.

The dependent variables in the logistic regression model included: right/left hamstring/quadriceps strength ratio, right/left ACL maximum laxity measurements, right/left hamstring length, right/left navicular drop and gender (Table 4.5). The final model equation used was:

$$\text{Log(injury)} = 3.238+3.286\text{RQHratio}-0.196\text{RKTmax}-1.175\text{LND}-0.024\text{RHOP}$$

Analysis of the final logistic regression model indicated that left navicular drop was the strongest predictor for injury compared to the other measures ($P = 0.005$) when comparing injured to non-injured cadets. A series of R Square Tests (Nagelkerke and Cox & Snell) were run to determine the validity of the model. The highest value was from a Nagelkerke test which is the least restrictive of the R Square tests. The test

revealed that 0.13 (13%) of the injuries incurred by the cadets could be predicted by the regression model (Table 4.6).

Table 4.5 Logistic regression final model results

Variable	Model Log Likelihood	Sig. of the Change
RHQ RATIO*	-119.058	0.016
RKTMAX*	-119.044	0.017
LNAVDROP	-120.044	0.005
RHOP*	-118.023	0.054

*RHQ RATIO= Right hamstrings/quadriceps strength ratio
*RKTMAX= Right ACL laxity at manual maximum with KT-1000
*LNAVDROP= Left navicular drop
*RHOP= Right single-leg hop for distance

Table 4.6 Power of logistic regression model

Cox and Snell R square	Nagelkerke R Square
0.094	0.132

CHAPTER 5
DISCUSSION

General Demographics

Two hundred four Air Force Academy Cadets volunteered for our study (76% males, 24% females). The subject group comprised freshmen through senior college students with most subjects from the sophomore class. The average age was 20 years old with the ethnic background of the cadets predominately whites.

For the most part (96%), the cadets rated themselves in "very good" to "excellent" physical condition and that they exercised from 4-6 times a week. Comparing the mean knee flexion angles for hamstring length between males and females, males exhibited 30%-40% tighter hamstrings than women for both legs. Analysis of quadriceps and hamstring strength and the ratio between men and women revealed that males had 62%-63% the strength of hamstrings to quadriceps. For females, the average strength of their hamstrings was 54%-56% as strong as their quadriceps. The demographics of our study were very similar to a two year study on 449 Navy Seal trainees.[29] Their findings, with respect to injury rate, ethnic background and exercise frequency virtually matched our findings. The authors reported that similar characteristics existed between their study group and civilian endurance athletes.[29]

Injury Demographics

Of the 204 cadets, 31.4% (n=64) of the cadets experienced injuries during the 6-month tracking time frame. Of the overall injuries, 30.8% of the males were injured and

33.3% of the females were injured. This statistic is also similar to the Navy Seal study [29] where 33.2 % of the male subjects suffered lower extremity injury in the first 9 weeks of training. Of the overall injuries, 13% of the cadets injured their knees. "Knee sprain" was the predominant self-reported knee injury followed by various muscular strains. Interestingly, 65.6% (n=42) of the injured cadets did not report their injury to medical providers. A repeat of this occurred when 63.2% (n=12) of the cadets that experienced 2 injuries failed to report the injury to medical providers. The same was true for cadets sustaining 3 injuries (n=3). Males were responsible for 70.8% of the failure to report an injury. This alarming finding is in agreement with Almeida et al.[2] who reported that women were more likely to report injuries than men but that when unreported injuries were taken into account, there was no significant difference between rate of injury of males and females. This may have alarming repercussions if this is a common trend of the Air Force. Noyes et al.[38] conducted a study that concluded that the commonly encountered mild knee sprain may in fact be a serious knee injury whose severity is easy to underestimate. They found that a surprising 72% of the patients diagnosed with "typical knee sprains" actually had disruption of the anterior cruciate ligament (28% partial tear and 44% complete tear).[38] An underestimation of the extent of injury or a misdiagnosis can result in recurrent injury or a more severe injury. Lower leg and foot injury can have repercussions for the hip and the knee as well. A study conducted by Bullock-Saxton[12] indicated that local sensation changes and altered hip muscle function occur following severe ankle sprain. Thus, it is possible that a severe ankle sprain could be a precursor to strains of the gluteal, quadriceps and hamstrings muscles, which were frequently reported during injury tracking. It has been reported that musculoskeletal

injuries account for the majority of lost duty time.[7,10,11,13,16,31] Krentz and associates[31] point out that flight operations are carefully choreographed and controlled in order to minimize injury potential. However, the same preventive attitude does not pertain to recreational activities in the same hazardous environments. This is especially true at deployment sites, on aircraft carriers other remote sites, where, out of necessity, the work place is often the site of recreational activities. The necessity to balance the operational tempo stress by "blowing off some steam" is critical to the well-being and physical as well as psychological health of each member. The undeniable camaraderie that exists between military members is in large part due to their ability to work together as well as play together. This practice is often constructively controlled by the advent of intramural sports where squadrons compete against each other. Basketball, volleyball and football were noted to be the most likely sports that result in musculoskeletal injuries and lost duty time.[16,24,28,29,40]

Results

The results of our study indicate that the anthropometric measurements taken; hamstring flexibility, single-leg hop for distance, hamstring/quadriceps strength ratio, KT-1000 ACL laxity may not demonstrate significant differences between injured and uninjured groups or be predictors for dynamic injuries. A Chi Square analyses was conducted to determine if any of the above measurements were significantly different in the injured group as compared to the non-injured group. The results of our study did not reveal any significant differences between the injured to uninjured groups. (Appendix D).

Stepwise mechanical binomial logistic regression was performed to relate the measurements taken to the injury status of the subject. From the logistic regression, the

variables that were significant contributors to determining injury were identified through a Forward and Backward Stepwise Analyses. Analysis of the final logistic regression model indicated that left navicular drop was the strongest predictor for injury compared to the other measures when comparing injured to non-injured cadets. However, following a series of R Square Tests (Nagelkerke and Cox&Snell) to determine the power of the model, the highest value was 0.13 indicating that only 13% of the injuries incurred by the cadets could be predicted by the regression model (Table 4.6).

Our results were similar to previous researchers who had not reported significant relationships between static anthropometric measures and injury. Knapik et al.[30] was not able to demonstrate a significant relationships at 30 deg/sec, which is similar to isometric tests, comparing knee flexion/extension strength to injury occurrence. The authors stated that the higher velocity of 180 deg/sec may be closer to those experienced during athletic events. Cashmere and associates[14] failed to find a significant relationship between static measurements as well and concluded that static variables could not be used to predict dynamic movements and thus could not be used as predictors for injuries. Kaufman and colleagues[29] theorized that static measures have little value in predicting dynamic lower extremity function.

Left navicular drop was the only measurement that was a relatively strong predictor for injury (p=.005) when comparing injured to non-injured cadets. This is similar to Louden et al.[32] who reported a significant correlation to static postural measurements and ACL injuries, claiming that knee recurvatum and excessive navicular drop was a consistent discriminator between ACL-injured and noninjured groups. The theory was that it could act as a predictor for ACL injury. This could not be substantiated

by our study as only one ACL injury was reported. Tiberio[42] theorized that excessive STJ pronation, which causes internal tibial rotation creates a compensatory internal rotation of the femur. This, in turn, should adversely affect patellofemoral biomechanics, leading to patellofemoral dysfunction and pain. Our study was not able to substantiate this theory. The investigators for the previous studies had theorized that individuals with these structural "faults" would be predisposed to injury,[32,43] however, neither of the studies had included tracking of injuries.

Conclusions

The results of our study indicate that static measurements may not be the best predictors for dynamic injuries. This is in agreement with other prospective studies.[14,29,30] The previous studies that noted significant findings were retrospective or theoretical in design.[32,42,43] The power of our study was low due to the variety of knee injury types that subsequently lead to low numbers per injury. It is possible that a Type II error occurred because of this fact.[45] The noted trend of failing to report injury needs to be addressed for the future safety of military members.

Limitations and Strengths

A number of factors were present in the study that may have accounted for our results. One fact is that our design was prospective in nature. The previous investigations demonstrating significant results were predominantly retrospective or theoretical in nature as with the Louden[32] and Tiberio[42] studies. Hartig et al.[23] had significant findings based on an intervention protocol, which may not relate to prospective studies. The limitations of the study included a variety of factors. We were not able to mandate that the cadets administer to the testing. As a result, we were

dependant on any and all cadets that volunteered. Ideally, we wanted to measure and track freshmen cadets only but then it would not have been statistically relevant since only 19.6% (n=40) comprised the freshmen cadets. Another weakness was that the injuries tracked were self-reported through electronic mail. A questionnaire was submitted once a month to the subjects (Appendix B). This policy, however, may have been a strength because of injuries tracked that would have otherwise been unreported. Based on the obvious necessity to measure both legs of each subject, one of the measurements had to be sacrificed; the "Q angle". Based on the literature, we felt that all the other measurements were critical. Another limitation in the study was the length of the tracking period. Finally, it is very possible a type II error was committed due to the low power of our study. The variety of injuries incurred and the relatively low numbers of cadets per injury made it difficult to find significant relationships between the measurements taken and injury occurrence. This is in agreement with Twellaar et al.[45] who conducted a prospective study that encompassed four years. The investigators determined that the large variety of sports injuries and the subsequent low numbers for each injury was the explanation for their lack of significant findings.[45]

The major strength of the study was that this is the initial pilot study for the Air Force. No other studies have been published in medical or science journals to date addressing the relationship of lower extremities and injury prevention for the Air Force.

The relatively homogeneous nature of the subjects (structured eating, sleeping, and training schedule) is also helpful in minimizing other variables that would affect the outcome of our findings. Another strength was prior to testing, the evaluators conducted intra-tester reliability procedures to verify accuracy of data collection (Appendix C). To

eliminate inter-rater error, each evaluator conducted his or her tests to each subject individually.

Implications for Future Research

Studies must continue to establish predisposing factors which cause knee injury. Future studies need to include randomized, double-blind, prospective and longitudinal designs that encompass more than 6 months. More emphasis needs to be made in finding dynamic screening tools that may be more effective in predicting injury.

The Army, Navy, Marine Corps, and now the Air Force, have epidemiological and demographic data on the issue of lower extremity injury prevention. A Meta analysis that compiles all the data from previous studies on all four services can be conducted and analyzed to further illuminate the cause of the majority of lower extremity injuries and then devise efficient training/screening protocols to prevent such injury. In this way conclusions can be made across the board for the military as a whole so that focus can be spent on more proactive endeavors for the purpose of injury prevention.

De facto studies can be run from deployment areas such as South West Asia, and across Europe with a provider who is deployed during an Aerospace Expeditionary Force (AEF) for a 90 day duration. Surveys can be compiled to indicate mechanism of injury, perceived level of fitness, etc. to further pinpoint where these injuries are coming from.

Providers with sports medicine training can deploy with the AEF. Intramural sports are an integral part of deployment life, and in some cases, participation is mandatory. For the purpose of preventing injury, assign a provider (MD, PT, ATC) to work each of the intramural competitions to provide pre-game taping, stretching and other preventive techniques before play as well as provide on field/court assessment and

treatment of sports injuries as they occur for more accurate evaluation of severity of injury. The efficacy of this practice can be tested by tracking the number of injuries per competition when a provider is present and without a provider to see if there is a significant decrease in the number of injuries that occur. This practice would also eliminate the failure to report an injury due to a provider there on the scene to record it.

Prevention of injury to our military force is of paramount importance. The mission of the Air Force requires that each member is prepared to act quickly and efficiently to each mission-related task he or she is assigned. As downsizing occurs, a higher percentage of members are required to be on mobility status, ready to deploy at a moment's notice. Because deployment teams are mobilized with essential personnel only, an injured member is not easily replaced. As a result, the impact of that injury may not just affect the individual. The whole success of the mission may be at risk. Proactive strategies must be developed and implemented that will maximize our Force's ability to be ready and able to carry out any mission. Gamble and colleages[19] point out that the Armed Forces need to recognize that if ongoing military operations and related responses are to be effective, personnel should be trained prior to deployment and resources dedicated to maintain a strong and healthy military force whenever and wherever needed.[19]

The US Air Force is a strong, motivated force that tirelessly responds to any mission given them. With the identification of predisposing factors, specific training programs, modification of environments and proactive strategies can be utilized throughout the Air Force to protect our nations valuable resource.

APPENDIX A
IRB APPROVAL LETTERS

UNIVERSITY OF
FLORIDA

Health Center Institutional Review Board

PO Box 100173
Gainesville, Florida 32610-0173
Tel: (352) 846-1494
Fax: (352) 846-1497

MEMORANDUM

DATE: August 10, 2000

TO: Denis Brunt, Ed.D., PT
Box 100154

FROM: R. Peter Iafrate, Pharm.D.
Chairman, IRB-01

R. Peter Iafrate

SUBJECT: IRB Project 386 - 2000 Expires on 8/9/01

TITLE: EXPEDITED: THE RELATIONSHIP OF ANTHROPOMETRIC AND STRENGTH MEASUREMENTS TO THE LOWER-EXTREMITY INJURY HISTORY AND PREVENTION TO AIR FORCE CADETS: A PROSPECTIVE LONGITUDINAL STUDY

You have received IRB approval to conduct the above-listed research project. Approval of this project was granted on 8/10/00. ENCLOSED IS THE DATED, IRB-APPROVED INFORMED CONSENT FORM that must be used for enrolling subjects. You have approval ONLY until the date of expiration, which is given above.

YOU ARE RESPONSIBLE FOR APPLYING FOR RENEWAL OF THIS PROJECT PRIOR TO THE EXPIRATION DATE. Re-approval of this project must be granted before the expiration date, or the project will be automatically suspended. If suspended, new subject accrual must stop. Research interventions must also stop unless there is a concern for the safety or well being of the subjects. YOU ==> MUST <== RESPOND TO THE CONTINUING REVIEW QUESTIONS WITHIN 90 DAYS OR YOUR PROJECT WILL BE OFFICIALLY TERMINATED.

THE IRB HAS APPROVED EXACTLY WHAT WAS SUBMITTED. Any change in the research, no matter how minor, may not be initiated without IRB review and approval, except where necessary to eliminate hazards to human subjects. If a change is required due to a potential hazard, that change must be promptly reported to the IRB.

Any severe and unanticipated side effects or problems and all deviations from federal, state, university, or IRB regulations must be reported, in writing, within 5 working days.

Upon completion of the study, you are REQUIRED to submit a summary of the project to the IRB office.

RESEARCH RECORDS MUST BE RETAINED FOR 3 YEARS AFTER COMPLETION OF THE RESEARCH; if the study involves medical treatment, it is recommended that the records be retained for 8 years.

If VAMC patients will be included in this project, or if the project is to be conducted in part on VA premises or performed by a VA employee during VA-compensated time, review by the VA Subcommittee for Research is required.

You are responsible for notifying all parties about the approval of this project, including your co-Investigators and Department Chair. If you have any questions, please contact the IRB-01 office at (352) 846-1494.

cc: IRB File
Pharmacy, VA Research Center, Clinical Research Center

DEPARTMENT OF THE AIR FORCE

HEADQUARTERS UNITED STATES AIR FORCE ACADEMY

USAF ACADEMY COLORADO

MEMORANDUM FOR Capt Michael Ross 8 August 2000

FROM: HQ USAFA/XPR

SUBJECT: Approval of IRB Required Changes

1. The USAFA Institutional Review Board Administrator has reviewed the changes that you submitted for your protocol, FAC2000036 The Relationship of Anthropometric and Strength Measurements to Lower Extremity Injury in Air Force Academy Cadets, in accordance with IRB requirements. All IRB required changes have been completed.

2. You are approved to begin your research and recruit 200 subjects. Do not exceed the number of subjects for which you have been approved. If you will need additional subjects, please send a letter to the IRB Chair or Administrator requesting additional subjects.

3. Please place the following statement at the bottom of your recruitment material: 'Approved: USAFA IRB FAC2000036'. This will inform potential subjects that your research has been reviewed and approved.

4. A final report or progress report is due to our office by 31 May 2001. If we have not received a final report, we will send you a progress report reminder 1 month prior to it being due. A sample format for these reports is located on our web page: http://www.usafa.af.mil/irb/FinlFmt.doc

5. When you submit a final report for this research, all original informed consent documents <u>must</u> accompany the final report.

6. If you have any questions or I can be of further assistance, please don't hesitate to contact me at 333-3091 or the IRB Chair, Dr. George Mastroianni, 333-4218.

Dr. Kathleen A. O'Donnell
USAFA IRB Administrator

APPENDIX B
INJURY TRACKING FORM

1) APPROXIMATE DATE OF INJURY

2) WHICH LEG DID YOU HURT: RIGHT____ LEFT____ BOTH____

3) WHICH ACTIVITY DID INJURY OCCUR (mark with an x)

a-recreational sport___ b- military training___ c-exercise____ d-daily activity_____

4) ON WHICH SURFACE DID INJURY OCCUR

a-not applicable___ b-grass___ c-wood___ d-concrete___ e-stairs___
f-dirt/cinders___ g-asphalt___

5) WHICH CATEGORY MOST CLOSELY DESCRIBES THE ACTIVITY WHICH CAUSED INJURY

a-collision/person___ b-collision/object___ c-turning/twisting___ d-overuse___
e-stretching___ f-running____ g-other (please specify):

6) DID INJURY REQUIRE TREATMENT BY PROVIDER? Yes___ No____
If Yes, what was the name of your injury/diagnosis?

7) WHICH LIMB/JOINT WAS INJURED (Please give brief description of injury)

Hip____	Groin____	Foot____
Quadriceps___	Hamstring___	
Knee ____	Shin____	
Calf____	Ankle____	

8) Briefly Describe in your own words what happened and what you think the injury is (ie. sprained knee/ankle, torn ligament, muscle strain)

APPENDIX C
RELIABILITY MEASURES

Average Measure Reliability Coefficients	Intraclass Correlation (5,0)	Alpha	Standardized item alpha
Hamstring length	0.9970	0.9799	0.9853
KT-max	0.9987	0.9913	0.9928
KT-manual max	0.9972	0.9811	0.9813
Navicular Drop	0.9923	0.9488	0.9523
Hop Test	0.9810	0.8744	0.8831
Manual Muscle Test Strength Test	0.9756	0.8667	0.8789

APPENDIX D
CHI SQUARE TESTS

Table D.1: Gender to injury status

Crosstab

		INJURY STATUS		
		injured	Not injured	Total
GENDER	Male	48	108	156
	Female	16	32	48
Total		64	140	204

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	0.112[b]	1	0.708		
Continuity Correction [a]	0.025	1	0.8075		
Likelihood Ratio	0.111	1	0.709		
Fisher's Exact Test				0.726	0.433
Linear-by-Linear Association	0.112	1	0.738		
McNemar Test				0.00[c]	
No. of Valid Cases	204				

a. Computed only for a 2x2 table

b. 0 cells (0%) have expected count less than 5. The minimum expected count is 15.06

c. Binomial distribution used

Table D.2: Year to injury status

Crosstab

		INJURY STATUS		
		Injured	Not injured	Total
YEAR/DEGREE	1	12	34	46
	2	18	38	56
	3	22	40	62
	4	12	28	40
Total		64	140	204

1 = Senior, 2 = Junior, 3 = Sophomore, 4 = Senior

Chi Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.134	3	0.769
Likelihood Ratio	1.144	3	0.766
Linear-by-Linear Association	0.313	1	0.576
No. of Valid Cases	204		

Table D.3: Race to injury status

Crosstab

		INJURY STATUS		
		injured	Not injured	Total
RACE	1	52	121	173
	2	1	5	6
	3	6	10	16
	4	3	1	4
	5	2	3	5
Total		64	140	204

1 = White, 2 = Black, 3 = Hispanic, 4 = Asian, 5 = Other

Chi Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.730	4	0.316
Likelihood Ratio	4.462	4	0.347
Linear-by-Linear Association	1.844	1	0.174
No. of Valid Cases	204		

Table D.4: Perceived level of Physical Fitness to injury status

Crosstab

		INJURY STATUS		
		Injured	Not Injured	Total
Current Physical Fitness	fair	2	6	8
	good	21	41	62
	very	24	74	98
	excellent	17	19	36
Total		64	140	204

Chi Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.687	3	0.083
Likelihood Ratio	6.516	3	0.089
Linear-by-Linear Association	1.021	1	0.312
No. of Valid Cases	204		

Table D.5: Exercise frequency during past year to injury status

Crosstab

		INJURY STATUS		Total
		injured	Not injured	
Exercise frequency during past year	1/week		4	4
	2/week	4	6	10
	3/week	9	26	35
	4/week	10	31	41
	5/week	18	30	48
	6/week	17	31	48
	7/week	6	12	18
Total		64	140	204

Chi Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	20.683[a]	13	0.079
Likelihood Ratio	27.139	13	0.012
Linear-by-Linear Association	2.854	1	0.091
No. of Valid Cases	64		

a. 23 cells (82.1%) have expected count less than 5. The minimum expected count is 0.42

APPENDIX E
LOGISTIC REGRESSION ANALYSIS

Table E.1: Binary Stepwise Logistic Regression Analysis (Forward)

Classification Table [a,b]

			Predicted		
			INJURY STATUS		Percentage
	Observed		0.00	injured	Correct
Step 0	INJURY STATUS	0.00	0	64	0.0
		injured	0	138	100.0
	Overall Percentage				68.3

a. Constant is included in the model
b. The cut value is 0.500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step	Constant	0.768	0.151	25.81	1	0.000	2.15

Variables not in the Equation

			Score	df	Sig.
Step 0	Variable	RQHRATIO	3.132	1	0.077
		LQHRATIO	2.680	1	0.102
		RKTMAX	6.053	1	0.014
		LKTMAX	1.540	1	0.215
		GENDER(1)	0.079	1	0.778
		RNAVDROP	0.033	1	0.856
		LNAVDROP	6.131	1	0.013
		RHAM	0.427	1	0.514
		LHAM	0.029	1	0.864
		RHOP	1.679	1	0.195
		LHOP	0.840	1	0.359
	Overall Statistics		23.43	11	0.015

Classification Table [a]

	Observed		Predicted: INJURY STATUS 0.00	injured	Percentage Correct
Step 1	INJURY STATUS	0.00	2	62	3.1
		injured	2	136	98.6
	Overall Percentage				68.3
Step 2	INJURY STATUS	0.00	8	56	12.5
		injured	6	132	95.7
	Overall Percentage				69.3
Step 3	INJURY STATUS	0.00	13	51	20.3
		injured	10	128	92.8
	Overall Percentage				
Step 4	INJURY STATUS	0.00	17	47	26.6
		injured	12	126	91.3
					70.8

a. The cut value is 0.500

Model if term removed

Variable		Model log likelihood	Change in –2 Log Likelihood	df	Sig. Of the Change
Step 1	LNAVDROP	-126.151	6.160	1	0.013
Step 2	RKTMAX	-123.080	5.970	1	0.015
	LNAVDROP	-123.133	6.075	1	0.014
Step 3	RQHRATIO	-120.104	4.163	1	0.041
	RKTMAX	-120.538	5.032	1	0.025
	LNAVDROP	-121.882	7.718	1	0.005
Step 4	RQHRATIO	-119.058	5.774	1	0.016
	RKTMAX	-119.044	5.745	1	0.017
	LNAVDROP	-120.044	7.745	1	0.005
	RHOP	-118.023	3.704	1	0.054

a. Based on conditional parameter estimates

Table E.2: Binary Stepwise Logistic Regression Analysis (Backwards)

Variables not in the Equation

			Score	Df	Sig.
Step 1	Variables	RQHRATIO	4.940	1	0.026
		LQHRATIO	4.441	1	0.035
		RKTMAX	5.952	1	0.015
		LKTMAX	1.577	1	0.209
		GENDER(1)	0.448	1	0.503
		RNAVDROP	2.404	1	0.121
		RHAM	0.074	1	0.785
		LHAM	0.414	1	0.520
		RHOP	1.535	1	0.215
		LHOP	0.468	1	0.494
	Overall Statistics		17.556	10	0.063
Step 2	Variables	RQHRATIO	4.044	1	0.044
		LQHRATIO	3.331	1	0.068
		LKTMAX	0.468	1	0.494
		GENDER(1)	0.058	1	0.810
		RNAVDROP	2.079	1	0.149
		RHAM	0.412	1	0.521
		LHAM	0.124	1	0.725
		RHOP	2.301	1	0.129
		LHOP	0.724	1	0.395
	Overall Statistics		12.318	9	0.196
Step 3	Variables	LQHRATIO	0.377	1	0.539
		LKTMAX	0.579	1	0.447
		GENDER(1)	0.060	1	0.806
		RNAVDROP	1.648	1	0.199
		RHAM	1.113	1	0.291
		LHAM	0.017	1	0.895
		RHOP	4.158	1	0.041
		LHOP	2.033	1	0.154
	Overall Statistics		8.538	8	0.383
Step 4	Variables	LQHRATIO	0.527	1	0.468
		LKTMAX	0.610	1	0.436
		GENDER(1)	0.525	1	0.469
		RNAVDROP	1.875	1	0.171
		RHAM	0.045	1	0.832
		LHAM	0.023	1	0.881
		LHOP	0.000	1	0.995
	Overall Statistics		4.152	7	0.762

Table E.3: Final Model for Logistic Regression Analysis

	Model if term Removed			
Variable	Model Log likelihood	Change in –2 Log Likelihood	df	Sig. Of the Change
Step 1	LNAVDROP	-126.151	1	0.013
Step 2	RKTMAX	-123.080	1	0.015
	LNAVDROP	-123.133	1	0.014
Step 3	RQHRATIO	-120.104	1	0.041
	RKTMAX	-120.538	1	0.025
	LNAVDROP	-121.882	1	0.005
Step 4	RQHRATIO	-119.058	1	0.016
	RKTMAX	-119.044	1	0.017
	LNAVDROP	-120.044	1	0.005
	RHOP	-118.023	1	0.054

a. Based on conditional parameter estimates

Table E.4: R Squared Test for Power
Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	246.141	0.030	0.042
2	240.191	0.058	0.081
3	236.045	0.077	0.108
4	232.343	0.094	0.132

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Laura C. Fields hailed from California until she enlisted in the Air Force in 1980. She received her BA from Rutgers University in 1986, her BS from University of Maryland at Baltimore in 1992 and her Masters of Health Science at the University of Florida in 2001. She is currently a Captain in the United States Air Force assigned to the Air Force Academy as Officer in Charge of the Cadet Physical Therapy Clinic. She has a 15-year-old son, Dave, who enjoys traveling the world and experiencing all the adventures life has to offer with her.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Health Science.

Denis Brunt

Denis Brunt, Chair
Associate Professor of Physical Therapy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Health Science.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Health Science.

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